Hindawi
Journal of Food Quality
Volume 2024, Article ID 9874263, 1 page
https://doi.org/10.1155/2024/9874263

Retraction

Retracted: Modified Atmosphere Packaging of Chicken Thigh Meat: Physicochemical and Sensory Characteristics during the Frozen Storage Period

Journal of Food Quality

Received 23 January 2024; Accepted 23 January 2024; Published 24 January 2024

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] A. R. Al-Hilphy, M. H. Al-Asadi, J. H. Khalaf, A. Mousavi Khaneghah, and M. Faisal Manzoor, "Modified Atmosphere Packaging of Chicken Thigh Meat: Physicochemical and Sensory Characteristics during the Frozen Storage Period," *Journal of Food Quality*, vol. 2022, Article ID 8876638, 10 pages, 2022.

Hindawi
Journal of Food Quality
Volume 2022, Article ID 8876638, 10 pages
https://doi.org/10.1155/2022/8876638

Research Article

Modified Atmosphere Packaging of Chicken Thigh Meat: Physicochemical and Sensory Characteristics during the Frozen Storage Period

Asaad R. Al-Hilphy,[1] Majid H. Al-Asadi,[2] Jalilah H. Khalaf,[2] Amin Mousavi Khaneghah,[3] and Muhammad Faisal Manzoor[4]

[1]*Department of Food Science, College of Agriculture, University of Basrah, Basrah, Iraq*
[2]*Department of Animal Production, College of Agriculture, University of Basrah, Basrah, Iraq*
[3]*Department of Food Science and Nutrition, Faculty of Food Engineering, University of Campinas (UNICAMP), Campinas, Sao Paulo, Brazil*
[4]*School of Food and Biological Engineering, Jiangsu University, Zhenjiang, China*

Correspondence should be addressed to Muhammad Faisal Manzoor; faisaluos26@gmail.com

Received 21 January 2022; Revised 25 March 2022; Accepted 4 April 2022; Published 2 May 2022

Academic Editor: Rijwan Khan

This study aimed to explore the utilization of modified atmosphere packaging (MAP) for chicken thigh meat pieces (CTMP) during frozen storage periods (FSP) of 1, 30, 60, and 90 days at −18°C. The treatments were divided into seven groups which are control, vacuum, 15% O_2/15% N_2/70% CO_2, 30% N_2/70% CO_2, 50% O_2/50% N_2, 30% O_2/70% CO_2, and 1.5 ml clove essential oil. The results showed that treatment of 30% N_2/70% CO_2 was associated with a lower pH value than control. The pH, drip loss, TBA, peroxide number, and fatty acid percentage values were significantly ($p < 0.05$) increased as FSP rises. The effect of the MAP and muscle fiber index (MFI) was significantly different ($p < 0.05$) by the FSP. A decrease in the drip loss during storage and cooking when samples were treated with a MAP of 15% O_2/15% N_2/70% CO_2, 30% N_2/70% CO_2, and clove oil groups were noted. The lowest values of TBA, peroxide number, and fatty acid percentage were recorded using 15% O_2/15% N_2/70% CO_2, 30% N_2/70% CO_2, and clove oil groups, respectively. There was an improvement in all sensory characteristics of all MAP and clove oil treatments.

1. Introduction

Fresh poultry meat is widely consumed due to its high nutritional value, while because of the chemical nature of meat, its products are subject to spoilage during storage [1, 2]. Preserving the nutritional value of meat and extending its shelf life has aroused the interest of producers and consumers in the development and use of modern technologies in food processing and to secure the health aspect [3–5]. Among the effective factors on consumer acceptance, color is playing an important role in extending the market as a quality indicator. It is also an index of the freshness of the product [6]. Maintaining the desired color for a long time is one of the major hypotheses of new packaging ways [7, 8]. It also has a significant effect on the meat appearance and acceptance of the way it is presented, which is one of the critical characteristics of the consumer [9–11].

MAP usually contains a mixture of gases, i.e., O_2, which makes the color more stable, CO_2, which inhibits microorganism's growth, and N_2, which prevents deformation of the can shape [12–14]. MAP improves the meat quality, such as color [15, 16], shelf life [17, 18], and safety of meat [19]. MAP is one of the deactivation methods proposed for the inhibition of the growth of microorganisms in different food products [20]. MAP with CO_2 has a significant effect on microorganisms' development because CO_2 (under anaerobic conditions) is elevated during chilled storage, which encourages to lower growing lactic acid bacteria [21].

The current study is vital to manufacturing a simple device to apply MAP technology in meat packaging. Moreover, the previous studies [18, 22, 23] compared among MAP treatments, but in the current study, we compared among MAP treatments with different gases ratios and using essential oils, as well as control atmosphere packaging (using CO_2 and N_2). This study aimed to investigate the impact of MAP and FSP on the physical, chemical, and sensory properties of CTMP.

2. Materials and Methods

2.1. Chicken Thigh Meat. In this study, 168-laying aged chicken ISA brown hens (G. *gallus domesticus*) were used. The birds were approximately 1.5 years old with a mean weight of 1.6 ± 0.21 kg. The birds were slaughtered manually, and after complete depletion for 150 seconds, the feathers and internal entrails were removed manually. Then, the thighs were cut from carcass and stored at 4 ± 1°C in the refrigerator until further analysis. Totally, 84 CTMP was used in the experiments, one piece was put in every polyethylene pouch, and the air was discharged by using a vacuum film sealing device (model FO2011, Hofer, German). After that, bags were treated as control, vacuum, 15% O_2/15% N_2/70% CO_2, 30% N_2/70% CO_2, 50% O_2/50% N_2, 30% O_2/70% CO_2, and clove oil (1.5 ml) at various FSP (1, 30, 60, and 90 days) storage at −18°C. The treatments were replicated three times.

2.2. Modified Atmosphere Packaging System. MAP system manufactured by Khalaf et al. [15] was used in the present study, as shown in Figure 1. At the beginning of the work, the delivery valves were installed on the packaging bags and punctured with a needle, and then they were filled with meat, emptied from the air, and closed tightly thermally. Then, the envelope is placed on the sensitive scale and zeroed, and the charging tube is installed on the delivery valve. The valve of one of the gases is slowly opened and noticed the weight change, and until it reaches the required limit, it is stopped immediately, and so on for the rest of the gases; each experiment is repeated three times, and then, it is stored at 4 ± 1°C. The significant limitations of the proposed method are that the current application is limited to meat, and it needs to carry out for other meat types and fruits. Also, it needs special bags (provided with a small delivery valve) to control charging gases in the bags.

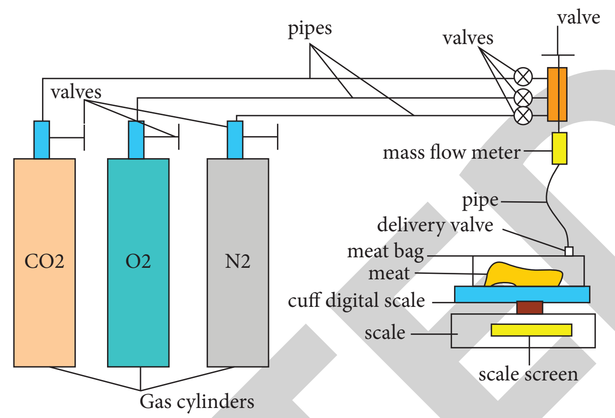


Figure 1: MAP system for CTMP at packaging.

2.3. pH. The method mentioned by AOAC [24] was followed using a pH meter (Lovibond Sensodirect pH 200, Germany), 5 g of minced CTMP was mixed with 100 ml of distilled water, put in a beaker, and then after five min, the value of pH has been estimated.

2.4. Muscle Fiber Index (MFI). MFI was calculated depending on the procedure mentioned by Jeremiah and Martin [25]; where the frozen cubes of CTMP were jumbled with 50 ml of 0.25 M sucrose 0.02KCL solution. Then, the pieces were stayed 5 min after thawing and crushed for 40 seconds at high strength and then filtered by a filter paper. The precipitate is taken and dried at 40°C temperature in an oven for 40 min, according to the following formula:

$$\text{MFI} = \text{weight of the precipitate}\,(g) \times 100. \quad (1)$$

2.5. Drip Loss (DL). The meat sample was weighed, then tied with a thin cotton thread, placed in small nylon bags, and suspended in the refrigerator for 48 hours at 4°C. Then, the sample was weighed after drying with the filter paper, and the drip loss was calculated as follows [26]:

$$\text{drip loss} = \left(\frac{(\text{weight of the original sample} - \text{weight of the sample after 48 hours of weighing the sample})}{\text{weight of the original sample}}\right) \times 100. \quad (2)$$

2.6. Cooking Loss. Mast Rasmussen [27] was calculated by roasting the samples (thigh) in an oven at 200°C for 15 minutes and was calculated according to the following equation:

$$\text{cooking loss} = \left(\frac{\text{weight before cooking} - \text{weight after cooking}}{\text{weight before cooking}}\right) \times 100. \quad (3)$$

2.7. Chemical Properties

2.7.1. Peroxide Value (PV). PV was determined depending on the Nielsen et al.'s [28] method. 3 g of finely minced meat, 30 ml of a mixture consisting of CH_3COOH, $CHCl_3$ (2 : 3), 5 ml of saturated KIO_3, 20 ml of distilled water, and starch indicator (little drops) and then titrated with 0.001 standard $Na_2S_2O_3$ solutions till the blue color disappeared, and the PV is calculated as follows:

$$\text{PV} = \frac{Na_2S_2O_3 \times N \times 1000}{W}, \quad (4)$$

where W is the sample weight (g), PV is the PV (meq./kg oil), and N is the normality.

2.7.2. Free Fatty Acids (FFA). FFA was measured depending on the Nielsen et al. [28] method. 3 g of meat and 50 ml of ethyl alcohol at 98% concentration were added, then drops of phenolphthalein index were added to the sample after heating it in a water bath till boiling, and then cleared. 0.1 N KOH solution was added to the mixture until the color of the solution turned to light pink, and the following equation calculated the FFA:

$$FFA = \frac{\text{titration}\,(A - B) \times N \times 282 \times 1000}{W \times 1000}. \quad (5)$$

where A is the number of milliliters of KOH titrated with the oil or fat sample, B is the number of milliliters of KOH titrated with the plank sample, and 282 is the oleic acid molecular weight.

2.7.3. Thiobarbituric Acid (TBA). The method of Nielsen et al. [28] has been used to determine the TBA value. 5 g of grounded meat was dissolved in 10 ml of $CHCl_3$ and put in a water bath for 5 minutes at a temperature of 60°C, and 10 ml of a 0.07% of TBA solution (in water mixed with the same volume of CH_3COOH) was added up to it; then, the mixture was centrifuged (1000 rpm for five min), and then the suds were taken and placed in a boiling water bath for 30 minutes. The absorbance was measured at a wavelength of 532 nm at room temperature, and the TBA value was determined as mg of malonaldehyde MDA/kg oil. The concentration of malonaldehyde was calculated as follows:

$$\text{malonaldehyde concentration}\left(\frac{mg\text{MDA}}{kg}\right) = \text{optical absorption} \times 7.8. \quad (6)$$

2.8. Sensory Assessment. The meat (chicken thigh) was cut into small cubes, and then an electric oven was used at a temperature of 200°C for 15 minutes to grill meat. Ten expert panelists conducted the sensory evaluation who were chosen from the department of food sciences, the University of Basrah to evaluate the samples in color expression, tenderness, flavor, juiciness, and overall acceptance of chicken meat thighs using nine hedonic scales (1–9 scores) according to ISO8586-1 [29].

2.9. Statistical Analyses. A factorial experiment with a completely random design (7 × 4) used seven types of modified atmosphere packaging (control, vacuum, 15% O_2/15% N_2/70% CO_2, 30% N_2/70% CO_2, 50% O_2/50% N_2, 70% CO_2/30% O_2, and oil of clove), and varied FSP (1–90 days) at −18°C with triplicate. The test has been utilized to contrast the treatment means at a significant level of 0.05, and the analysis was conducted using the SPSS program ver. 25.

3. Results and Discussion

3.1. Physical Properties

3.1.1. pH. Table 1 presents the influence of the MAP and the FSP on the pH of CTMC. The results showed that the MAP and FSP have a significant ($p < 0.05$) influence on the pH value, where the pH value at 30% O_2/70% CO_2 was 5.75 during the one-day FSP, where it reached 5.75 compared to the control treatment, which reached 5.88 in the same frozen storage period. While the pH value increased in the 90-day FSP for the same treatment, it reached 5.87 and 6.22, respectively, and the reason may be due to the low pH value of meat. Water, resulting in the formation of carbonic acid (−3HCO), causes slight acidity in meat [30]. Therefore, it is observed that the pH values decreased at 15% O_2/15% N_2/70% CO_2, 30% O_2/70% CO_2, and 30% N_2/70% CO_2. Higher pH results in a darker color and high water tolerance; the texture is coarse and easy to spoil; lower pH results in dull color and lower water-bearing capacity; meat texture is

Table 1: Impact of average gas sulfa MAP and FSP on the CTMP pH.

Treatments	FSP (day)			
	1	30	60	90
Control	5.88 ± 0.01^{fg}	5.75 ± 0.30^{pq}	5.97 ± 0.01^{c}	6.22 ± 0.01^{a}
Vacuum	5.84 ± 0.02^{k}	5.89 ± 0.02^{f}	5.95 ± 0.02^{d}	6.10 ± 0.01^{b}
30% N_2/70% CO_2	5.83 ± 0.01^{kl}	5.74 ± 0.01^{qr}	5.77 ± 0.02^{no}	5.86 ± 0.01^{hi}
30% O_2/70% CO_2	5.75 ± 0.01^{pq}	5.77 ± 0.01^{no}	5.83 ± 0.01^{kl}	5.87 ± 0.02^{gh}
50% O_2/50% O_2	5.78 ± 0.03^{mn}	5.75 ± 0.01^{pq}	5.85 ± 0.01^{ij}	5.89 ± 0.02^{f}
15% O_2/15%/70% CO_2	5.79 ± 0.02^{m}	5.76 ± 0.01^{op}	5.79 ± 0.02^{m}	5.85 ± 0.01^{ij}
Clove oil	5.75 ± 0.01^{pq}	5.83 ± 0.01^{kl}	5.85 ± 0.01^{ij}	5.93 ± 0.01^{e}

tender. There is a direct effect of the relationship between pH, water tolerance, and dark color, where high pH was observed in storage periods from 60 to 90 days due to water retention of meat, and this is consistent with Zakrys-Waliwander et al. [31] who illustrated that the meat pH decreased when the MAP was used in the medium. The pH value is related to the degree of color if it is dark or light. The high pH value of 5.8 or more increases the water holding capacity with a dark color and coarse building of the muscles, in addition, to provide suitable conditions for microbial corruption, either for the low pH value of 5.5 or fewer leads to the appearance of the transparent color, and the muscles are soft in structure with a prolonged storage period [32]. Nowak and Krysiak [33] indicated a decrease in the pH value after storage meat for a while in commercial MAP with a concentration of 60% CO_2 and 40% N_2 compared to storage meat in vacuum packaging.

3.1.2. Muscle Fiber Index (MFI). Table 2 shows the MAP and FSP on the MFI in the CTMP. The results showed that the MAP and the FSP have a significant ($p < 0.05$) effect on the MFI of CTMP, where the treatment of 30% N_2/70% CO_2 at the one-day FSP gave the lowest value in MFI, which was 84.66 compared to the control. In the 90-day FSP, MFI reached 191.33. After 90 days of frozen storage period and using clove oil gave a lower MFI (93) at one day of FSP because of the antioxidant activity of clove oil. MFI was increased as FSP increased. When FSP increased from 1–90 days, the MFI increased from 106–170.66 using an MAP of 15% O_2/15% N_2/70% CO_2, respectively. The lower value of MFI was 84.66 using an MAP of 70% CO_2 + 30% N_2 at one day of FSP. Denaturation of protein is determined depending on increasing MFI in the chilled and super-chilled chicken breast meat during storage of myofibrils fragmentation is related to the degree of proteolysis during meat storage [34]. In vacuum packaging, MIF was increased from 108 to 176 when FSP increased from 1 to 90 days. To compare among treatments, control, vacuum, 30% N_2/70% CO_2, 30% O_2/70% CO_2, 50% O_2/50% N_2, 15% O_2/15% N_2/70% CO_2, and clove oil were increased by 71.85, 64.76, 94.1, 47.67, 76, 61, and 74.9% when FSP increased from 1–90 days, respectively.

3.1.3. Drip Loss. Table 3 illustrates MAP and FSP on the drip loss of CTMP. The results showed significant ($p < 0.05$) differences in drip loss in meat treated by MAP during FSP. 30% N_2/70% CO_2, 30% O_2/70% CO_2, 15% O_2/15% N_2/70% CO_2, 50% O_2/50% N_2, and clove oil were given the lowest drip loss as it reached 3.33 3.12, 3.96, 3.54, and 3.46%, respectively, compared to the control treatment in one day of FSP. The vacuum treatment gave the highest drip loss and was very close to the control treatment in one day of FSP. High oxygen concentration is instrumental in water retention in meat, resulting in reduced drip loss during storage [35]. Drip loss in MAP-coated chicken meat was more than that of vacuum-packed [18].

The results illustrated that all treatments gave a significant increase ($p < 0.05$) in the drip loss during FSP, and the amount of drip loss was changed during FSP, with the highest value being in the 90 days of FSP in control (7.13%). At the same time, it reached to the lowest value at the FSP of one day at the treatment of 30% N_2/70% CO_2, which amounted to 32.1%. The frozen storage period negatively influences drip loss [30]. Drip loss depends on the amount of meat in the MAP package and storage time, and when storage time increased from 0 to 30 days, drip loss increased from 0 to 7.7%, respectively, using 100% CO_2 [36]. The amount of drip loss during storage and cooking is the amount of water bonding with meat muscle protein. The higher the amount of drip loss from the meat, the lower the nutritional value of the meat due to the loss of proteins, vitamins, and minerals [37]. Liquid loss using vacuum packaging was reduced by 3.43% compared to control, and the maximum reduction reached 33.04% using 70% CO_2 + 30% N_2 at 1 day of FSP. Little reduced liquid loss using vacuum packaging because of the pressure on meat led to the increased liquid loss.

3.1.4. Cooking Loos. The impact of MAP and FSP on the cooking loss of CTMP is shown in Figure 2. Treatment of clove oil in the one day of FSP showed that the cooking loss was 13.31%, while the highest value of cooking loss reached 28.45 in the control treatment after 90 days of FSP. Cooking loss was increased as FSP increased for all treatments, i.e., when FSP was raised from 1 to 90 days, the cooking loss increased from 14.29 to 21.26%, respectively, using MAP of 15% O_2/15% N_2/70% CO_2. These results agree with Marcinkowska-Lesiak et al. [38], who showed that storage life is important and increases cooking loss. The increase in moisture loss during cooking with increasing storage period is a natural result of the increase in the content of exogenous enzymes [39]. The rate of moisture loss during cooking

Table 2: Impact of MAP and FSP on the MFI of CTMP.

Treatments	FSP (day)			
	1	30	60	90
Control	111.33 ± 1.16^{n}	166.00 ± 1.00^{e}	175.00 ± 1.35^{c}	191.33 ± 1.52^{a}
Vacuum	108.00 ± 2.00^{o}	155.66 ± 1.37^{h}	166.00 ± 2.64^{e}	176.00 ± 2.64^{c}
30% N_2/70% CO_2	84.66 ± 3.72^{q}	142.00 ± 2.19^{k}	152.00 ± 2.08^{i}	164.33 ± 3.78^{f}
30% O_2/70% CO_2	121.66 ± 2.50^{m}	162.33 ± 2.08^{g}	170.66 ± 2.08^{d}	179.66 ± 2.88^{b}
50% O_2/50% N_2	100.00 ± 1.00^{p}	153.66 ± 0.57^{i}	166.00 ± 2.64^{e}	176.00 ± 1.65^{c}
15% O_2/15% N_2/70% CO_2	106.00 ± 1.29^{r}	149.66 ± 1.52^{j}	160.33 ± 1.68^{g}	170.66 ± 2.08^{d}
Clove oil	93.00 ± 2.64^{s}	132.00 ± 2.24^{l}	151.66 ± 3.21^{i}	162.66 ± 2.51^{g}

Table 3: Influence of MAP and FSP on drip loss (%) of CTMP.

Treatments	FSP (day)			
	1	30	60	90
Control	4.66 ± 0.02^{d}	5.32 ± 0.02^{c}	6.63 ± 0.12^{b}	7.13 ± 0.05^{a}
Vacuum	4.50 ± 0.03^{d}	5.18 ± 0.01^{c}	6.25 ± 0.02^{b}	6.64 ± 0.02^{b}
30% N_2/70% CO_2	3.12 ± 0.02^{f}	4.52 ± 0.01^{d}	5.25 ± 0.05^{c}	6.33 ± 0.05^{b}
30% O_2/70% CO_2	3.96 ± 0.02^{e}	4.32 ± 0.01^{d}	5.15 ± 0.02^{c}	6.08 ± 0.08^{b}
50% O_2/50% N_2	3.54 ± 0.02^{e}	3.80 ± 0.02^{e}	4.28 ± 0.02^{d}	5.69 ± 0.01^{bc}
15% O_2/15% N_2/70% CO_2	3.33 ± 0.01^{f}	4.53 ± 0.01^{d}	5.13 ± 0.02^{c}	6.13 ± 0.01^{b}
Clove oil	3.46 ± 0.01^{e}	4.44 ± 0.01^{d}	5.33 ± 0.01^{c}	6.33 ± 0.01^{b}

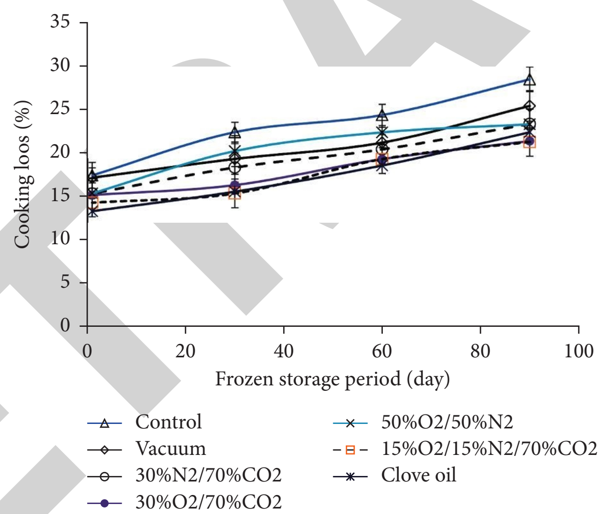


Figure 2: Cooking loss vs. FSP at different MAP treatments of CTMP.

increases after 15 days of storage, and if muscle tissue storage progresses, the increase in moisture loss during cooking leads to a change in the structure of muscle protein [40]. There is no significant difference between vacuum packaging and control in cooking loss because vacuum generates lower pressure around the meat, extracting liquids from meat.

3.2. Chemical Properties

3.2.1. TBA. The impact of MAP and FSP on the TBA value in CTMP is shown in Figure 3. The results showed that the FSP of 90 days for all MAP treatments showed a significant ($p < 0.05$) increase in the TBA compared to the rest of the FSP. It is also noted from the results that the lowest value of TBA was when using 15% O_2/15% N_2/70% CO_2 and vacuum treatment, which amounted to 0.27 and 0.26 mg MDA/kg, respectively, in the one day of FSP, while the highest value of TBA was in the 90 days of FSP. The results also showed that clove oil gave TBA values ranging between 0.31 and 0.65 mg MDA/kg for the FSP from 1 to 90 days. This indicates that the rancidity in this treatment is the lowest of all treatments. Dang et al. [18] confirmed that lipid oxidation in MAP-coated chicken breast fillets was lower than in vacuum packs (0.47 versus 0.62 mg MDA/kg, respectively). Flaczyk et al. [41] reported that the smell and taste of rancid fat result from low-molecular-weight volatile substances such as ketones, aldehydes, or free fatty acids. The phenomenon of fat oxidation leads to undesirable changes that affect its sensory qualities, such as color, texture, flavor development, and

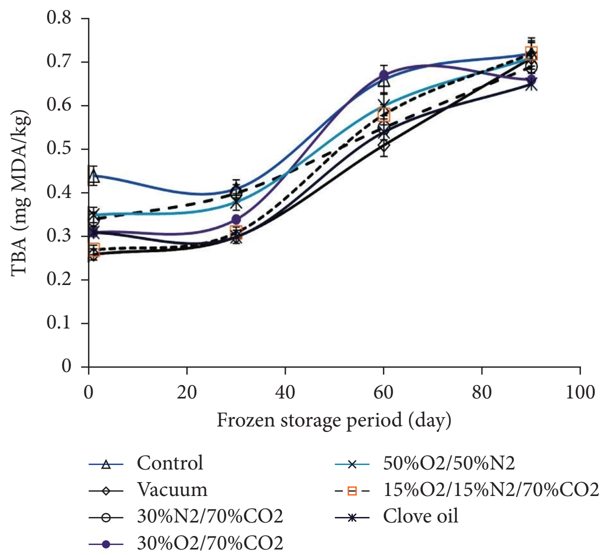


FIGURE 3: TBA vs. FSP at different MAP treatments of CTMP.

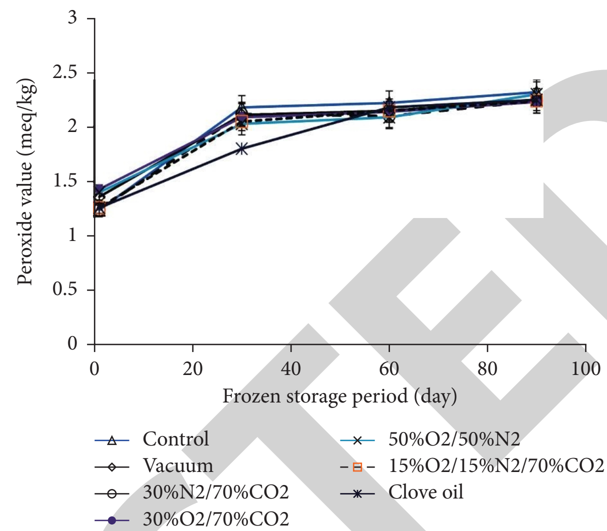


FIGURE 4: Peroxide value vs. MAP treatments and FSP.

smell. In addition, meat loses its quality of nutrition and health [42]. Antioxidant supplements can improve meat quality by modulating muscle metabolic processes, including enzymes, whose activity may also be affected by packaging [43]. One of the leading causes of meat spoilage is the oxidation processes after converting muscle to meat or during meat processing and storage. However, the chemical changes responsible for turning muscle boil to meat lead to stopping the balance of the antioxidant body and thus facilitate the oxidation reactions of meat after slaughtering the animal [44]. Abdullah and Buchtová [45] treated chicken skin and wings by 80% O_2 + 20% CO_2 (MAP-O_2) and 70% N_2 + 30% CO_2 (MAP-N_2) and found that TBARS was increased with MAP-O_2, and while MAP-N_2 increased, the shelf life of the product is increased.

3.2.2. Peroxide Value. Figure 4 shows the effect of MAP treatments and FSP on the peroxide value for CTMP. The results illustrated a significant ($p < 0.05$) effect for the MAP and FSP on the peroxide value. The FSP of 90 days and the MAP treatment of 50% O_2/50% N_2 presented the highest peroxide value, 2.30 meq/kg, compared to the MAP treatment of 30% N_2/70% CO_2 at the one day of FSP, which was 1.24 meq/kg. The results illustrated no significant ($p > 0.05$) variation between the treatments of MAP, control, and clove oil in the one day of FSP. The results indicated significant variations ($p < 0.05$) between MAP treatments at 30 days of FSP, where the incline in the peroxide value was observed when using clove oil, which reached 1.80 meq/kg. The reason for the high peroxide value in control treatment may be due to chemical changes (oxidative rancidity) of fats as a result of the action of microorganisms that sort enzymes that break down fats, which in turn lead to fat oxidation and fatty acids formation as a result of the breakdown of the ester bonds between fatty acids and cholesterol. The formation of free radicals and the unsaturated bonds of fatty acids are the primary targets that free radicals cause oxidative stress, primarily linoleic and linolenic essential fatty acids [46]. The peroxide number, which expresses the oil content of peroxide compounds, was estimated by the reaction of saturated potassium iodide at room temperature (KI) in an acidic solution with oxygen bound in the form of peroxide in the oil, which will produce several iodine equivalents that are equivalent to the number of oxygen equivalents. It is most common in stored foods, including carcass meat. The short-chain fatty acids, aldehydes, and ketones are the products of the oxidation process and are responsible for the rancid flavor in the meat. The value of the peroxide number ranges from 3–5 meq/kg, and the lower than this range, the more extended the storage period of the meat [47].

3.2.3. Free Fatty Acids. Figure 5 depicts the free fatty acids (FFA) vs. MAP treatments and FSP. The results showed that FAA significantly ($p < 0.05$) varied by MAP and FSP treatments, i.e., MAP treatment of 15% O_2/15% N_2/70% CO_2 and 50% O_2/50% N_2 in one-day FSP reached 0.46 and 0.43%, respectively. The results revealed that using MAP treatments at 30 and 60 days of FSP gave a significant difference ($p < 0.05$) in FFA compared to the control treatment, and it does not vary significantly ($p > 0.05$) over 90 days of FSP. As the storage period progresses, the increase in fatty acids in chicken leg meat may be due to a rise in the FFA content due to rancidity, a breakdown of the ester bond between fatty acids and cholesterol, and an increase in lipase activity [48]. The fat in meat contains a percentage of free fatty acids that increase in the incorrectly stored meat, which causes the fat to go rancid during storage as a result of its oxidation by atmospheric air or its hydrolysis by enzymes of microorganisms, which determine the age and quality of the fat in the meat. The lower the percentage of free fatty acids below 1.2, the lower the percentage of oxidation, thus increasing the shelf life of meat and improving its nutritional quality [47].

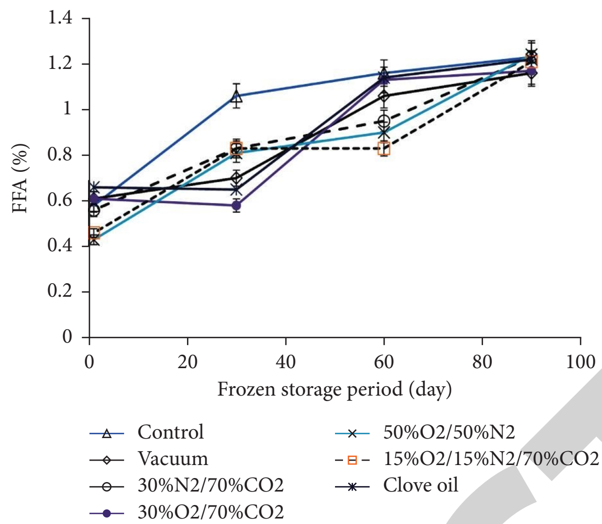


Figure 5: Free fatty acids (FFA) vs. MAP treatments and FSP.

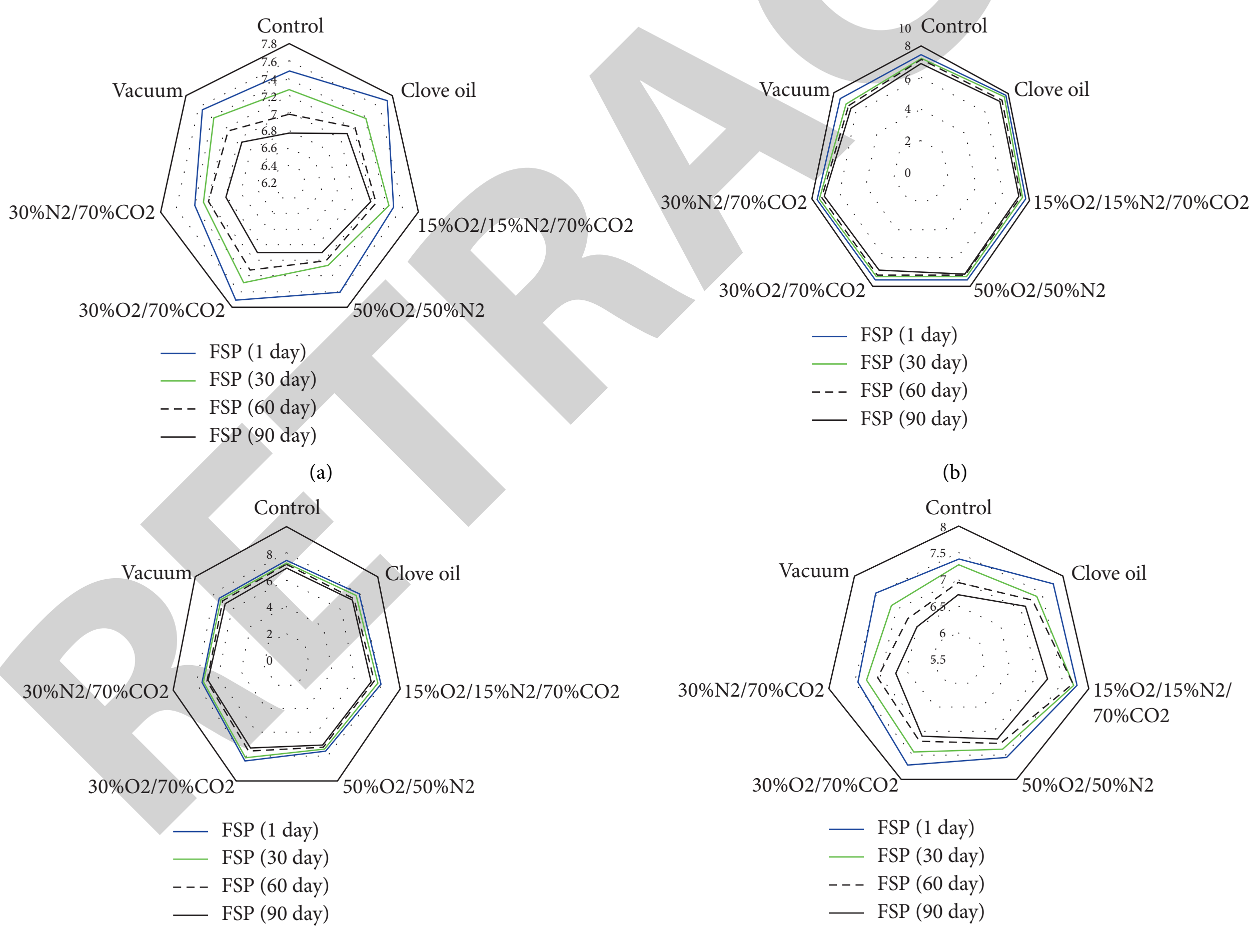
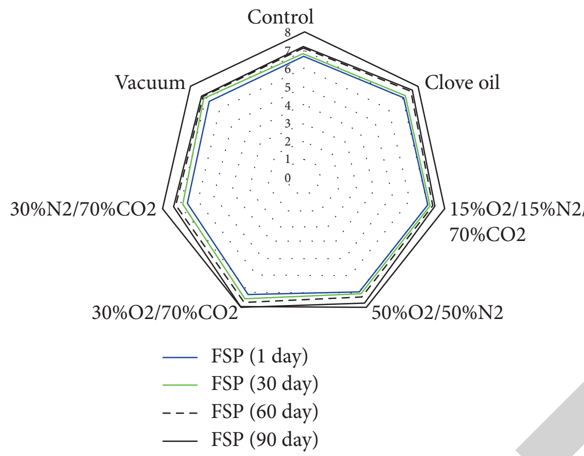


Figure 6: Continued.



(e)

Figure 6: The effect of MAP treatments and FSP on the sensory assessment: (a) color; (b) juiciness; (c) tenderness; (d) flavor; and (e) overall acceptance of CTMP.

3.3. Sensory Assessment. Figure 6(a) shows the MAP and the FSP on CTMP color. In terms of the interaction between MAP treatments and FSP, the results clarified that the interaction effect was significant ($p < 0.05$), as the treatment of 50% O_2/50% N_2 and clove oil in the FSP for one day gave the highest value in color reached 7.60 and 7.71, respectively., while it appears from the Figure that the lowest value was in the vacuum treatment at 90 days of FSP, which amounted to 6.94, while it was in the control treatment in the same FSP, reached 6.77. When fats are oxidized, hydroperoxides enhance decomposition reactions [49].

Figure 6(b) illustrates the impact of MAP treatments and FSP on the juiciness of CTMP. The results presented that juiciness of chicken thighs meat treated by MAP of 15% O_2/15% N_2/70% CO_2 and 30% O_2/70% CO_2 at FSP of 1 day was significantly increased ($p < 0.05$) compared to the other treatments which reached 8.27 and 8.33, respectively, while in control and vacuum treatments were inclined to 6.88 and 6.77, respectively, at 90 days of FSP. Muscles stored in deflated casings gave a higher moisture loss during storage than muscles stored in casings (MAP) due to the pressure disturbance to which meat is exposed in vacated casings [35].

Figure 6(c) disclosed the influence of MAP treatments and FSP in the tenderness of chicken thighs meat. Treatment of 15% O_2/15% N_2/70% CO_2 and clove oil at one day of FSP gave the highest values, which were 7.71 and 7.77, respectively, while the control and vacuum treatments have the lowest values, which were 6.88 and 6.44, respectively. This is because clove oil and CO_2 gas significantly impact meat tenderness.

Figure 6(d) clarified the influence of MAP treatments and FSP on the flavor of CTMP. The results showed that the treatments 15% O_2/15% N_2/70% CO_2 and clove oil gave a significant increase ($p < 0.05$) in the flavor compared to the rest of the treatments, which amounted to 7.77 7.77, respectively, at the one day of FSP. The flavor of CTMP by control and treated by vacuum treatments at 90 days of frozen storage period reached 6.71 and 6.49, respectively. The decrease in flavor values may be due to the progression of storage periods, as the lengthening of the storage period affects the volatile fatty acids that give flavor to meat, while the MAP works to preserve the volatile fatty acids [50].

Figure 6(e) influence of MAP treatments and FSP on the overall acceptance of chicken thigh meat. The treatment 30% O_2/70% CO_2 at one day of FSP gave the highest value in the overall acceptance characteristic, which was 7.99, while it was found through the results of Figure 4 that the lowest value obtained in control, 30% N_2/70% CO_2 treatment, and vacuum which were 6.71, 6.60, and 6.71, respectively, in 90 days of FSP.

4. Conclusions

During this study, a considerable enhancement in the physical properties of the meat treated with MAP was observed. The treatment of 30% N/70% CO_2 showed an improvement in the tenderness property due to an inclined muscle fiber index value and a rise in pH. MAP using 15% O_2/15% N_2/70% CO_2 gave lower cooking loss than the other treatments. Clove oil gave lower TBA and peroxide values. MAP treatments gave FFAs lower than the control. MAP of 30% O_2/70% CO_2 gave a higher MFI at all FSPs than other treatments. The differences between MAP of 30% N_2/70% CO_2 and 15% O_2/15% N_2/70% CO_2 were insignificant ($p < 0.05$) and gave a lower liquid loss. In general, cooking loss, TBA, FFAs, and MFI were increased as FSP increased. The sensory properties of all the MAP and clove oil treatment treatments were improved (took higher scores). The FSP had a significant ($p < 0.05$) influence on the chemical, physical, and sensory characteristics. MAP treatments have a significant effect on chemical characteristics. The interaction between MAP treatments and FSP significantly affects the physical, chemical, and sensory characteristics. Significant advantages of this work are extended shelf life, improved meat quality, and simple design and the workers no need special training to deal with CTMP. Significant limitations are current application is limited for meat and needs special bags. The major attributes of the dataset to decide whether the user is abnormal or normal are lower peroxide value, free fatty acids and TBA, and higher FSP. Future possibilities are manufacturing continuous CTMP or increasing the volume of present CTMP for treatment chicken meat to use in meat-processing factories. Moreover, for the treatment of other meat such as duck and cow, the application of pulse moderate alternative electric field in CTMP increases its effectiveness.

Data Availability

The dataset used to support the findings of this study is included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Asaad R. Al-Hilphy, Majid H. Al-Asadi, Jalilah H. Khalaf, and Amin Mousavi Khaneghah conceptualized the study and contributed to formal analysis, data curation, and writing of the original draft. Muhammad Faisal Manzoor took part in data curation and visualization and revised the original draft.

Acknowledgments

The authors thank the Department of Food Science, the University of Basrah, for providing food engineering lab and facilities.

References

[1] A. R. Al-Hilphy, M. H. Al-Asadi, N. K. Al-Hmedawy et al., "Effects of electrical field stimulation on the physicochemical and sensory attributes of aged chicken meat," *Journal of Food Process Engineering*, Article ID e14032, 2022.

[2] N. Hussain, C. H. Weng, and N. Munawar, "Effects of different concentrations of pineapple core extract and maceration process on free-range chicken meat quality," *Italian Journal of Food Science*, vol. 34, no. 1, pp. 124–131, 2022.

[3] A. M. Belmonte, P. Macchioni, G. Minelli, C. Scutaru, L. A. Volpelli, and D. P. Lo Fiego, "Effects of high linolenic acid diet supplemented with synthetic or natural antioxidant mix on live performance, carcass traits, meat quality and fatty acid composition of Longissimus thoracis et lumborum muscle of medium-heavy pigs," *Italian Journal of Food Science*, vol. 33, no. 2, pp. 117–128, 2021.

[4] X. Zhang, X. Li, M. Yang, X. Yang, and F. Zhao, "Effect of antioxidant extracted from bamboo leaves on the quality of box-packaged sturgeon fillets stored at 4°C," *Quality Assurance and Safety of Crops and Foods*, vol. 12, no. 2, pp. 73–80, 2020.

[5] F. Zouaghi and M. J. Cantalejo, "Study of modified atmosphere packaging on the quality of ozonated freeze-dried chicken meat," *Meat Science*, vol. 119, pp. 123–131, 2016.

[6] N. M. Lynch, C. L. Kastner, and D. H. Kropf, "Consumer acceptance of vacuum packaged ground beef as influenced by product color and educational materials," *Journal of Food Science*, vol. 51, no. 2, pp. 253–255, 1986.

[7] H. Gazalli, A. H. Malik, H. Jalal, S. Afshan, A. Mir, and H. Ashraf, "Packaging of meat," *International Journal of Food Nutrition and Safety*, vol. 4, no. 2, pp. 70–80, 2013.

[8] H.-S. Lee, Y. I. Park, and S. Kang, "Effects of fat meat and storage temperature on the qualities of frozen minced beef products," *Quality Assurance and Safety of Crops and Foods*, vol. 13, no. 1, pp. 93–104, 2021.

[9] A. S. A. Al-Obaidi, A. B. Mahmood, Z. K. Khidhir, H. G. Zahir, Z. T. Al-doori, and H. Othman Dyary, "Effect of different plants' aromatic essential oils on frozen Awassi lamb meat's chemical and physical characteristics," *Italian Journal of Food Science*, vol. 33, no. 4, pp. 98–106, 2021.

[10] M. Bashiry, H. Hoseini, A. Mohammadi et al., "Industrial and culinary practice effects on biologically active polyamines level in Turkey meat," *Quality Assurance and Safety of Crops and Foods*, vol. 13, no. 2, pp. 67–78, 2021.

[11] M. Karpinska-Tymoszczyk, "The effect of antioxidants, Packaging type and frozen storage time on the quality of cooked Turkey meatballs," *Food Chemistry*, vol. 148, pp. 276–283, 2014.

[12] M. Jakobsen and G. Bertelsen, "Colour stability and lipid oxidation of fresh beef. Development of a response surface model for predicting the effects of temperature, storage time, and modified atmosphere composition," *Meat Science*, vol. 54, no. 1, pp. 49–57, 2000.

[13] J. P. Kerry, M. N. O'Grady, and S. A. Hogan, "Past, current and potential utilisation of active and intelligent packaging systems for meat and muscle-based products: a review," *Meat Science*, vol. 74, no. 1, pp. 113–130, 2006.

[14] O. Sørheim, H. Nissen, and T. Nesbakken, "The storage life of beef and pork packaged in an atmosphere with low carbon monoxide and high carbon dioxide," *Meat Science*, vol. 52, no. 2, pp. 157–164, 1999.

[15] J. H. Khalaf, M. H. Al-Asadi, and A. R. Al-Hilphy, "Influence of modified atmosphere packaging and frozen-storage period in the colour characteristics of poultry meat," *Basrah Journal of Agricultural Sciences*, vol. 32, no. 2, pp. 60–73, 2019.

[16] E. Mahdavi and P. Ariaii, "Characterization of functional fish ham produced from Silver carp (*Hypophthalmichthys molitrix*) surimi enriched with natural antioxidant and vegetable fiber," *Italian Journal of Food Science*, vol. 33, pp. 127–136, 2021.

[17] F. A. A. Abdullah and H. Buchtova, "Comparison of qualitative and quantitative properties of the wings, necks and offal of chicken broilers from organic and conventional production systems," *Veterinarni Medicina*, vol. 61, no. 11, pp. 643–651, 2016, þ.

[18] T. T. Dang, T. M. Rode, and D. Skipnes, "Independent and combined effects of high pressure, microwave, soluble gas stabilization, modified atmosphere and vacuum packaging on microbiological and physicochemical shelf life of precooked chicken breast slices," *Journal of Food Engineering*, vol. 292, Article ID 110352, 2021.

[19] J. Huang, Y. Guo, Q. Hou, M. Huang, and X. Zhou, "Dynamic changes of the bacterial communities in roast chicken stored under normal and modified atmosphere packaging," *Journal of Food Science*, vol. 85, no. 4, pp. 1231–1239, 2020.

[20] R. B. Waghmare and U. S. Annapure, "Combined effect of chemical treatment and/or modified atmosphere packaging (MAP) on quality of fresh-cut papaya," *Postharvest Biology and Technology*, vol. 85, pp. 147–153, 2013.

[21] K. Czerwiński, T. Rydzkowski, J. Wróblewska-Krepsztul, and V. K. Thakur, "Towards impact of modified atmosphere packaging (MAP) on shelf-life of polymer-film-packed food products: challenges and sustainable developments," *Coatings*, vol. 11, no. 12, p. 1504, 2021.
[22] Y. Guo, J. Huang, Y. Chen, Q. Hou, and M. Huang, "Effect of grape seed extract combined with modified atmosphere packaging on the quality of roast chicken," *Poultry Science*, vol. 99, no. 3, pp. 1598–1605, 2020.
[23] N.-D. M. Luong, S. Jeuge, L. Coroller et al., "Spoilage of fresh Turkey and pork sausages: influence of potassium lactate and modified atmosphere packaging," *Food Research International*, vol. 137, Article ID 109501, 2020.
[24] Aoac, "Official methods of analysis," 2016, http://www.eoma.aoac.org/methods/info.asp?ID=16264.
[25] L. E. Jeremiah and A. H. Martin, "Effects of prerigor chilling and freezing and subcutaneous fat cover upon the histological and shear properties of bovine longissimus dorsi muscle," *Canadian Journal of Animal Science*, vol. 62, no. 2, pp. 353–361, 1982.
[26] C. Z. Alvarado and A. R. Sams, "The influence of postmortem electrical stimulation on rigor mortis development, calpastatin activity, and tenderness in broiler and duck pectoralis," *Poultry Science*, vol. 79, no. 9, pp. 1364–1368, 2000.
[27] A. L. Rasmussen and M. G. Mast, "Effect of feed withdrawal on composition and quality of broiler meat," *Poultry Science*, vol. 68, no. 8, pp. 1109–1113, 1989.
[28] S. S. Nielsen, M. C. Qian, and O. A. Pike, "Fat characterization," in *Food Analysis Laboratory Manual*, S. Nielsen, Ed., Springer, Berlin, Germany, pp. 185–194, 2017.
[29] ISO8586-1, *Sensory Analysis, General Guidance For The Selection, Training, And Monitoring of Assessors*, International Organization for Standardization, Geneva, Switzerland, 1993, https://www.iso.org/standard/15875.html.
[30] M. H. Abdalhai, M. Bashari, C. Lagnika, Q. He, and X. Sun, "Effect of ultrasound treatment prior to vacuum and modified atmosphere packaging on microbial and physical characteristics of fresh beeffied atmosphere packaging on microbial and physical characteristics of fresh beef," *Journal of Food and Nutrition Research*, vol. 2, no. 6, pp. 312–320, 2014.
[31] P. I. Zakrys-Waliwander, M. G. O'Sullivan, E. E. O'Neill, and J. P. Kerry, "The effects of high oxygen modified atmosphere packaging on protein oxidation of bovine M. longissimus dorsi muscle during chilled storagefied atmosphere packaging on protein oxidation of bovine M. longissimus dorsi muscle during chilled storage," *Food Chemistry*, vol. 131, no. 2, pp. 527–532, 2012.
[32] M. A. Taher, *The Science of Meat*, Basrah University press, Basrah, Iraq, 1990.
[33] A. Nowak and E. Krysiak, "Predominant microflora of vacuum packed frankfurters," *Polish Journal of Food and Nutrition Sciences*, vol. 14, pp. 91–94, 2005.
[34] P. Kaewthong, L. Pomponio, J. R. Carrascal, S. Knøchel, S. Wattanachant, and A. H. Karlsson, "Changes in the quality of chicken breast meat due to superchilling and temperature fluctuations during storage," *The Journal of Poultry Science*, vol. 56, no. 4, pp. 308–317, 2019.
[35] R. M. Delles and Y. L. Xiong, "The effect of protein oxidation on hydration and water-binding in pork packaged in an oxygen-enriched atmosphere," *Meat Science*, vol. 97, no. 2, pp. 181–188, 2014.
[36] A. L. Holck, M. K. Pettersen, M. H. Moen, and O. Sørheim, "Prolonged shelf life and reduced drip loss of chicken filets by the use of carbon dioxide emitters and modified atmosphere packaging," *Journal of Food Protection*, vol. 77, no. 7, pp. 1133–1141, 2014.
[37] M. M. Metheny, H. C. Lee, S. Viliani, D. C. Bennett, S. Hurley, and I. Kang, "Improvement of chilling efficiency and meat tenderness of broiler carcasses using subzero saline solutions," *Poultry Science*, vol. 98, no. 9, pp. 4190–4195, 2019.
[38] M. Marcinkowska-Lesiak, Ż. Zdanowska-Sąsiadek, A. Stelmasiak et al., "Effect of packaging method and cold-storage time on chicken meat quality," *CyTA—Journal of Food*, vol. 14, no. 1, pp. 41–46, 2016.
[39] N. Jama, V. Muchenje, M. Chimonyo, P. E. Strydom, K. Dzama, and J. G. Raats, "Cooking loss components of beef from Nguni, Bonsmara and Angus steers," *African Journal of Agricultural Research*, vol. 3, pp. 416–420, 2008.
[40] A. Iwanowska, E. Iwańska, B. Grześ et al., "Changes in proteins and tenderness of meat from young bulls of four breeds at three ages over 10 days of cold storage," *Animal Science Papers And Reports*, vol. 28, pp. 13–25, 2010.
[41] E. Flaczyk, J. Kobus-Cisowska, and M. Jeszka, "Influence of Ginkgo biloba leaves extracts on oxidative stability of meat lipids of boiled dough pockets filled with meat stored in refrigerated conditions," *Nauka, Przyroda, Technologie*, vol. 3, no. 4, p. 117, 2009.
[42] M. Gómez and J. M. Lorenzo, "Effect of packaging conditions on shelf-life of fresh foal meat," *Meat Science*, vol. 91, no. 4, pp. 513–520, 2012.
[43] S. M. Kang, G. Kang, P.-N. Seong, B. Park, and S. Cho, "Evaluation of various packaging systems on the activity of antioxidant enzyme, and oxidation and color stabilities in sliced Hanwoo (Korean Cattle) beef loin during chill storage," *Asian-Australalasian Journal of Animal Sciences*, vol. 27, no. 9, pp. 1336–1344, 2014.
[44] Y. Kumar, D. N. Yadav, T. Ahmad, and K. Narsaiah, "Recent trends in the use of natural antioxidants for meat and meat products," *Comprehensive Reviews in Food Science and Food Safety*, vol. 14, no. 6, pp. 796–812, 2015.
[45] F. A. A. Abdullah and H. Buchtová, "Selected freshness indices of skin and wings from organic chicken packaged in modified atmosphere," *Acta Veterinaria Brno*, vol. 89, no. 1, pp. 97–105, 2020.
[46] D. Rubén, P. Mirian, G. Mohammed, J. Francisco, W. Barba, and M. L. José, "A comprehensive review on lipid oxidation in meat and meat products," *Antioxidants*, vol. 8, p. 429, 2019.
[47] R. M. Mahmood, A. M. Saleh, S. A. A. W. Mahdi, and A. M. Saleh, "Effects of soy sauce and some other additives on lipid oxidation and its related properties of minced beef meat during cold storage," *IOP Conference Series: Earth and Environmental Science*, vol. 910, no. 1, Article ID 012053, 2021.
[48] N. Sara, P. P. Chong, S. Jinap, N. Noordiana, H. I. Lokman, and F. A. R. Ahmad, "Molecular regulation of lipogenesis, adipogenesis and fat deposition in chicken," *Genes*, vol. 12, p. 414, 2021.
[49] J. Lorenzo, R. Domínguez, and J. Carballo, "Control of lipid oxidation in muscle food by active packaging technology," in *Natural Antioxidants. Applications in Foods of Animal Origin*, R. Banerjee, A. K. Verma, and M. W. Siddiqui, Eds., CRC Press, London, UK, pp. 343–382, 2017.
[50] L. G. Fidalgo, M. M. Q. Simões, S. Casal, J. A. Lopes-da-Silva, I. Delgadillo, and J. A. Saraiva, "Enhanced preservation of vacuum-packaged Atlantic salmon by hyperbaric storage at room temperature versus refrigeration," *Scientific Reports*, vol. 11, no. 1, pp. 1668–1713, 2021.